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ADA 056647

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TOP 6-2-559	2. GOVT ACCESSION NO. A056647	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ELECTROMAGNETIC RADIATION ANALYSIS		5. TYPE OF REPORT & PERIOD COVERED Test Operations Procedure
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s) DAEA18-76-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Electronic Proving Ground ATTN: STEEP-MT-I Fort Huachuca, Arizona 85613		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DARCOM-R 310-6
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Test and Evaluation Command ATTN: DRSTE-ME Aberdeen, MD 21005		12. REPORT DATE 10 April 1978
		13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

electromagnetic radiation
electromagnetic radiation effects
electromagnetic radiation hazard levels
field strength versus distance characteristics
susceptibility threshold levels
threat equipments

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A methodology is given for determining whether electromagnetic radiation of sufficient strength to cause performance degradation to the test item exists at the test item location. The results of an electromagnetic radiation effects test are used to identify the radio frequencies and electromagnetic radiation levels to which the test item is susceptible. Further, using a test bed, comparisons are made with the representative signal levels to determine if the

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20. ABSTRACT (Cont)

levels at which the test item suffers performance degradation would occur in the field. Signal transmission characteristics are developed for each radiation source to provide recommended minimum separation criteria.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-105
*Test Operations Procedure 6-2-559
AD No.

10 April 1978

ELECTROMAGNETIC RADIATION ANALYSIS

1. SCOPE.

This Test Operations Procedure (TOP) describes the methodology required to determine whether degradation in test item performance will occur because of radio frequency (RF) radiation levels in the intended environment that exceed the susceptibility level of the test item. A computer model simulating a tactical deployment is used to determine the parameters of electromagnetic radiation (EMR) at the test item location due to emitters in the simulated deployment. Empirical susceptibility data are obtained for the test item at the frequencies which the computer model identifies as potential interfering emitter frequencies. The interferers to the test item are identified by matching the signal type to which the equipment is susceptible to the emitters in the tactical deployment generating the signal. The minimum separation distance between the test item and a potential interferer for noninterference operation will be calculated for those emitters which are potential interferers but which are not contained in the simulated deployment. Appendix B provides a convenient check list for preparation, performance, and analysis of tests.

2. FACILITIES AND INSTRUMENTATION.

a. A mathematical model for computing the EMR level due to emitters in a simulated tactical deployment, at the test item location.

*This TOP supersedes Materiel Test Procedure (MTP) 6-1-006-3, 15 July 1975.

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b. A simulated deployment test bed for the operational time frame of the test item and, as a minimum, should include the communications electronics (C-E) equipment used in support of the Army in the field, with appropriate tactical air and opposing forces and electronic warfare equipments. Civilian electromagnetic environment data will be used in the analysis when available.

c. Emitters and associated support equipment to provide a test field strength in order to establish the EMR level at which the test item is susceptible for each frequency tested.

3. PREPARATION FOR TEST.

3.1 Planning. The following general preparation steps will be taken:

a. Select test equipment having calibration expiration dates which will not expire during the expected term of the test.

b. Select the test bed with the deployment in which the test item is most likely to be used. Deploy the test item in the test bed using guidance from the Basis of Issue (BOI), approved requirements document, and Technical Characteristics (TC) documents. Obtain validation of the modified test bed from the Communications Research and Development Command (CORADCOM). Choose a snapshot time which will provide maximum EMR activity at the test item location.

c. Review all instructional material and reports of previous similar tests conducted on the same types of equipment that may be issued with the test item by the manufacturer, contractor, or Government. Keep these documents readily available for reference.

d. Prepare record forms for systematic entry of data, which should include the pretest equipment record, chronology of test, test results, and any observations and measurements that would be of value in the analysis and final evaluation.

e. Prepare a test item sample plan sufficient to ensure that enough samples of all measurements are taken to provide statistical confidence of final data in accordance with MTP 3-1-002[1/] (as a minimum, the test item sample plan should provide for the taking of data on three test items). Provide for modifications during test progress, as may be indicated by monitored results.

f. Prepare adequate precautions to provide safety for personnel and equipment, ensure that all safety standard operating procedures are

1/ MTP 3-1-002, Confidence Intervals and Sample Sizes, 25 January 1967.

observed throughout the test, and ensure that the item has successfully completed the examination prescribed in MTP 6-2-507[2/] and TECOM Regulation 385-6.[3/]

3.2 Personnel

Ensure that all test personnel are familiar with the required technical and operational characteristics of the item under test, such as those stipulated in the approved requirements document and TC, and also with safety precautions which must be observed during the test.

4. TEST CONTROLS.

Test controls will be selected which are consistent with the functional nature of the test item.

5. PERFORMANCE TESTS.

5.1 Data Required. Record the following information:

a. Nomenclature, serial number, manufacturer's name, and function of the item under test.

b. Nomenclature, serial number, accuracy tolerances, calibration requirements, and next calibration date of the test equipment selected for the test and other ancillary equipment used to perform the tests.

c. Operating conditions and modes, control settings, and electrical loads and terminations used during the test.

d. The location and description of the test site, orientation of the test item with respect to the EMR emitter antenna, date and time of test, names of test personnel, subtest designation, and test condition or operating mode. The test configuration shall be shown in block form.

e. Frequencies (MHz), signal levels (V/m), modulation, and polarization characteristics of the RF field that caused the test item to malfunction.

5.2 Method

a. Determine the EMR level that is due to emitters in the simulated deployment at each test item location in the test bed as a function of frequency. For each frequency of radiation present at the test item locations, select the highest level of radiation which exists at any of the sites. This can be either the maximum as produced by the antenna mainlobe or the

2/ MTP 6-2-507, Safety, March 1967.
3/ TECOM Regulation 385-6, Verification of Safety of Materiel During Testing, 6 May 1969.

maximum at the various test item locations as produced by the antenna orientations specified in the deployment. Identify the equipment (nomenclature, frequency, modulation type, and antenna polarization) generating the EMR field.

b. Plot the data showing maximum radiation as a function of frequency. Use these data as a guide to select the EMR emitter frequencies for the empirical tests.

c. The test item will be operated under conditions sufficient to exercise all system functions.

d. The EMR emitter will be tuned to the first test frequency and its emission level increased until (1) a test item performance degradation or system failure is observed, (2) the EMR emitter power limit is reached, or (3) the maximum field level specified for the test item is reached, whichever occurs first. The results will be recorded.

e. The EMR emitter will then be tuned successively to the other required test frequencies, and step 5.2d will be repeated with the exclusion of measurements at the first test frequency, for each test item operating condition, signal polarization, and modulation.

6. DATA REDUCTION AND PRESENTATION.

a. EMR susceptibility test data shall be organized as shown in the first data form contained in appendix A.

b. The test data shall be further reduced as shown in figure 1. A "rounding down" process will be used as illustrated to represent susceptibility thresholds for the intervals between test frequencies.

c. To minimize the amount of data, field strength versus distance characteristics (fig. 2) will be presented only for those emitters operating on frequencies to which the item is susceptible.

d. Field strength versus distance characteristics, as shown in figure 2, will be developed for each radiation source and for its antenna mainlobe. The minimum distance separations which can reasonably be expected between the test item and radiation source will be compared with the threat distances shown by these characteristics.

e. The test bed emitter data shall be organized as shown in the second data form contained in appendix A.

f. The computer-aided analysis will produce a group of EMR levels in each frequency band at each test item location. The number of individual EMR levels is dependent on the number of emitters in a frequency band in the deployment and on how many produce levels at each location above a preselected cull level. The group of EMR levels will be assumed to be a

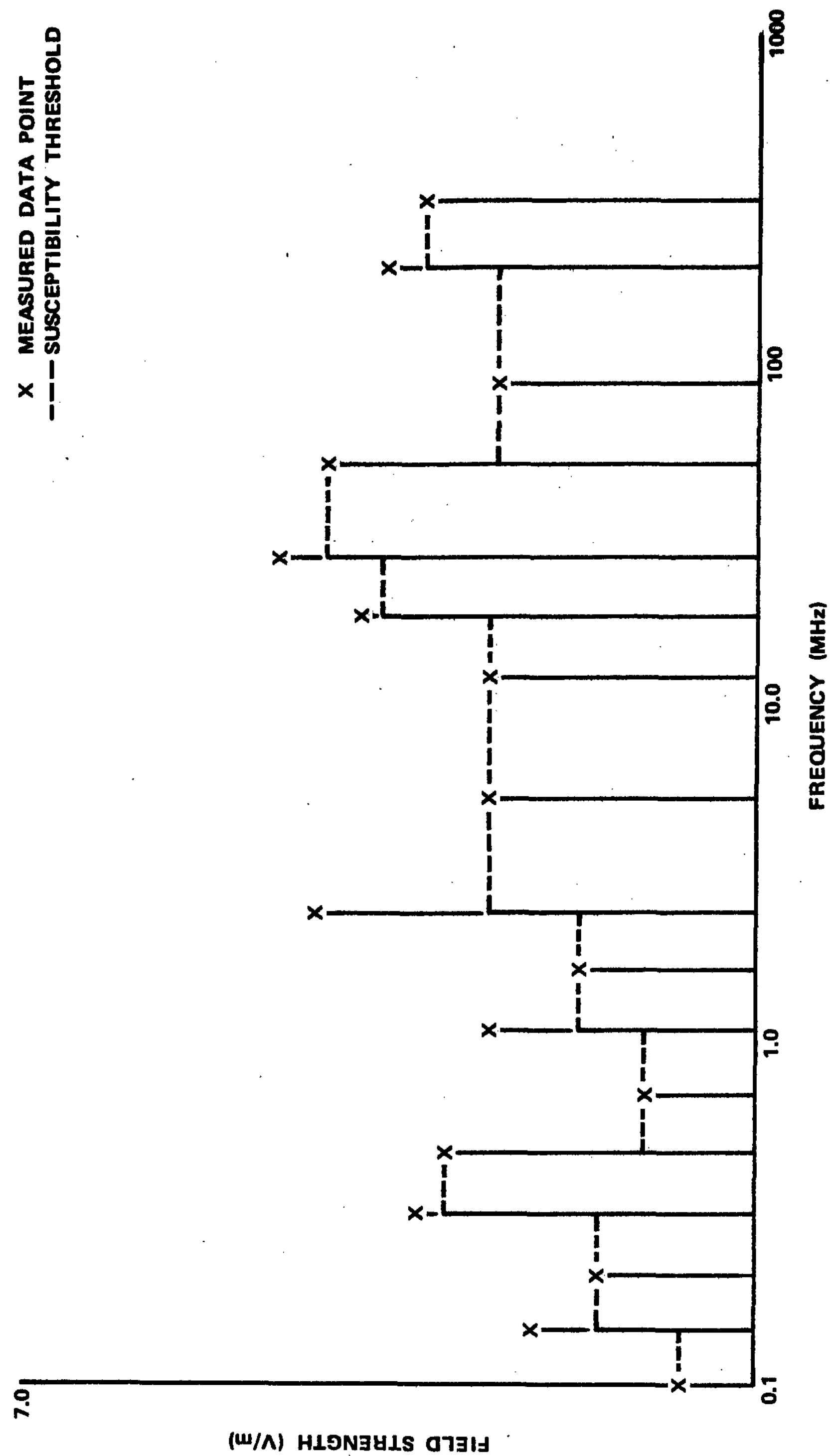

Figure 1. Representative susceptibility threshold.

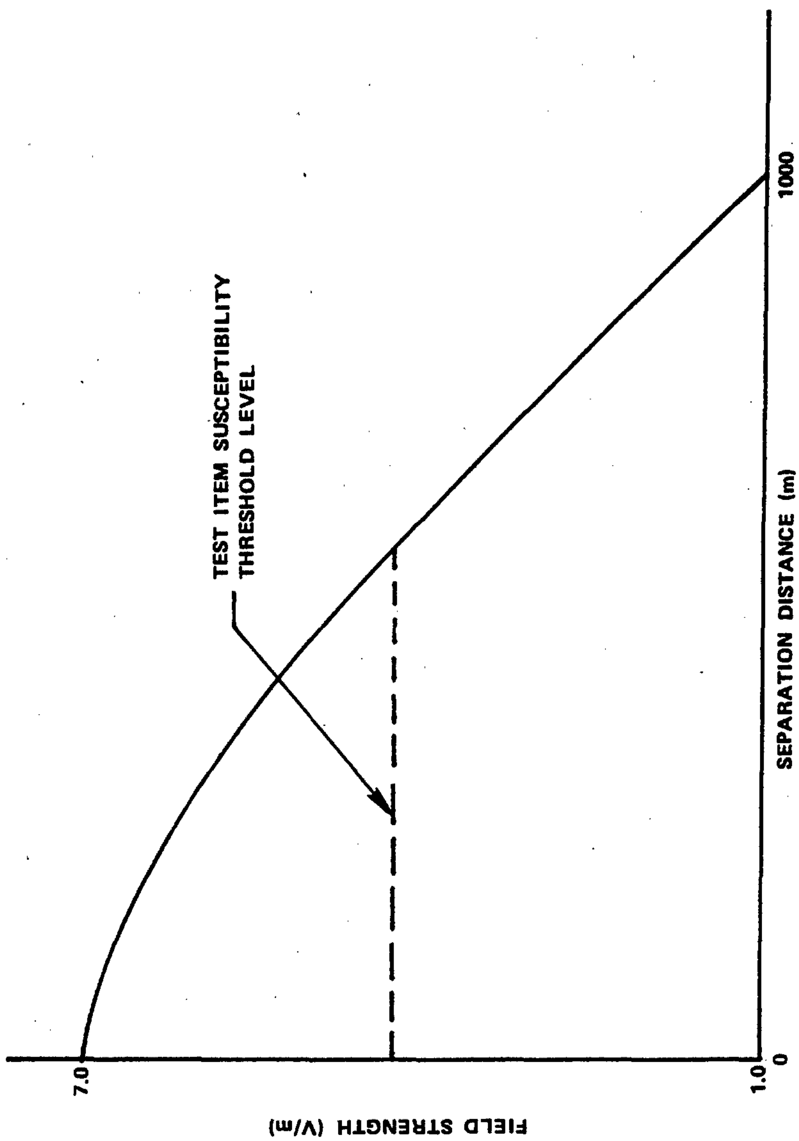

Figure 2. Field strength versus distance characteristics for emitter.

sample from a normal distribution. This assumption and the sample of EMR levels will be used to compute the maximum possible EMR level and the confidence level for the maximum which can occur at the test item for each frequency band. Because battlefield conditions are continuously changing in the actual situation, the EMR levels produced by antenna mainlobes will be used to develop the various EMR levels at test item locations to produce the most valid maximum EMR level predictions.

g. In some instances it can reasonably be expected that the test item will be located in the near field of some antennas. For these cases the near-field EMR levels and the field strength versus distance characteristics will reflect the results of the near-field computations. The near-field EMR levels produced in the vicinity of a perfectly conducting earth will be used for omnidirectional antennas. In the far-field region the levels will be computed by use of the Longley-Rice irregular terrain propagation path loss model.[4/]

h. The maximum levels computed as described in paragraphs f and g, above, will be compared with EMR levels which include not only degradation threshold levels but also hazard levels depending on the nature of the test item.

i. Minimum separation distances, to prevent performance degradation of the test item and to prevent hazardous conditions, will be identified.

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4/ Longley, A. G. and P. L. Rice, "Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain--A Computer Method--1968," ESSA Technical Report ERL 79-ITS 67, July 1968 (Revised September 1972).

APPENDIX A
FORMS FOR EMRE DATA COMPILATION

This appendix contains the data compilation forms for the following:

a. EMRE Measurement Results

b. EMRE Evaluation Results

EMRE MEASUREMENT RESULTS

Subtest:________________________________

Test Personnel:_______________ Test Site Location:__________

________________________ Date:__________

Test Item Characteristics:

a. Nomenclature:__________ d. Manufacturer:__________

b. Serial No.:__________ e. Function:__________

c. Significant Control Positions/Remarks:__________

Test Equipment:________________________________

Significant Control Positions/Remarks:____________________

Frequency (MHz)	Modulation	Polarization	Field Strength (V/m)	Failure Indication

EMRE EVALUATION RESULTS

Test Bed Emitter Configuration: ______________________________

____

____

____

Remarks: ______________________________

____

____

____

Test Item Site ID Number	Emitter Nomenclature	Frequency (MHz)	Modulation	Polarization	Signal Level (V/m)	Distance (m)

APPENDIX B
CHECKLIST

I. FACILITIES AND INSTRUMENTATION

A. FACILITIES REQUIRED FOR TEST

Have facilities been scheduled? ______

B. INSTRUMENTATION

1. Are EMR emitters and associated equipment requirements available for frequencies required? ______
2. Have they been scheduled? ______

II. PREPARATION FOR TEST

A. PLANNING

1. Is equipment within calibration limits? ______
2. Has guidance for proper deployment selection been established? ______
3. Has proper deployment been selected? ______
4. Have instructional material and reports been revised? ______
5. Have data sheets been prepared? ______
6. Are they complete? ______
7. Have deployment radiation levels been determined? ______
8. Have data been plotted? ______
9. Are data complete? ______

B. PERSONNEL

1. Have test personnel been familiarized with operating characteristics of test item? ______
2. Have personnel and equipment safety precautions been established? ______

C. DATA REQUIRED

1. Have all data on test item, test equipment, and ancillary equipment been recorded? ______
2. Have operating conditions, modes, control settings, loads, and terminations been recorded? ______
3. Have location, date, time, operator names, all test designators, and test conditions been recorded? ______
4. Have failure-causing signal characteristics been recorded? ______

III. TEST CONTROLS

Has the EMRE test facility specified test controls? ______

IV. PERFORMANCE TESTS

1. Have all system functions of test item been exercised? ______
2. Has EMR emitter test procedure been defined? ______

V. DATA REDUCTION AND PRESENTATION

1. Have data minimization and organization techniques been described? ______
2. Have EMR computer model techniques and parameters been described? ______
3. Are all data available? ______
4. Have all data been reduced? ______
5. Has amount of data presented been minimized? ______
6. Have all equipments been considered?

   Deployment ______
   FAEF ______
   Other ______

7. Have minimum separation distances been identified? ______
8. Is data presentation clear? ______
9. Have the objectives and criteria been answered with the analysis? ______

APPENDIX C
ELECTROMAGNETIC ENVIRONMENTAL TEST FACILITY

The Electromagnetic Environmental Test Facility (EMETF) is a Government-operated, contractor-supported facility of the U. S. Army Electronic Proving Ground (USAEPG), Fort Huachuca, Arizona, a testing activity of the U. S. Army Test and Evaluation Command. The primary mission of the EMETF is to analyze all electromagnetic environment effects of Army communications-electronics (C-E) equipment, systems, and concepts in real and simulated tactical situations. The EMETF has scientists, engineers, and analysts organized to handle on-going operational tasks and long-term developmental work. This scientific and engineering staff is supported by a technical publications group, administrative and logistics services group, and six interrelated facilities. These six facilities, except for the Field Facility, are located in Tucson, Arizona, and are listed below:

1. The Instrumented Workshop (IWS) provides precisely controlled facilities to test military -- including cryptographic -- and commercial C-E systems and equipments. Using automated data collection and performance scoring (both analog and digital) capabilities, the IWS can handle equipments requiring individual link commitment as well as complex major systems requiring rapid and accurate data correlation and analysis.

2. The Scoring Facility (SF) enables the EMETF to consider the human operators and their responses to equipment operating characteristics. These operator responses are measured through use of articulation scores which represent the percentage of phonetically balanced words in a test message correctly received by the operators, or team of trained listeners.

3. The Spectrum Signature Facility (SSF) provides the capability of performing measurements of all pertinent C-E equipment characteristics under both laboratory and field conditions. These measurements are used for verification of design concepts early in the equipment life cycle as well as for the identification of spectrum signatures of foreign military C-E devices.

4. The Weapon System Electromagnetic Environment Simulator (WSEES) is a highly versatile simulation and measurement laboratory that tests systems and equipment operating in the RF microwave region and develops performance scoring data for such systems and equipment. WSEES RF signals duplicate those signals which can be expected to occur in a real-world environment, and the performance scoring data include measurements of the reaction of an adaptive system to a changing environment.

5. The Field Facility (FF), located near Gila Bend, Arizona, is used to test equipment deployments and equipment characteristics which cannot be simulated or measured in the laboratory. Testing capabilities include cosite interference, RF radiation, open-field emission, and susceptibility measurements. The FF also provides realistic field conditions for acquiring and validating data in support of analyses performed with computer models.

6. The EMETF Analytical Facility provides computer support based on a CDC 6500 computer--a large-scale, solid-state, general-purpose digital computer system designed for multiprocessing and time-sharing, as well as general data processing and scientific applications. Input to the CDC 6500 is selected from an extensive library of computer models. The concept for these models has been validated by extensive field and laboratory measurements. The models simulate the electromagnetic environments of postulated situations and predict the performance of C-E and weapon system equipment in those situations.

APPENDIX D
DEFINITIONS

Electromagnetic Radiation. Radiation made up of oscillating electric and magnetic fields and propagated with the speed of light. Includes gamma, X-ray, ultraviolet, visible, and infrared radiation, and radar and radio waves.

Far Field Region. That volume of space extending beyond the far-field distance. The far-field distance is that distance between two antennas equal to D^2/λ or 3λ whichever is larger, where D is the maximum aperture dimension of the large antenna and λ is the wavelength at the fundamental frequency.

Field Strength. The term "field strength" shall be applied only to measurements made in the far field. The measurement may be of either the electric or the magnetic component of the field, and may be expressed as V/m, A/m, or W/m; any one of these may be converted to the others. For measurements made in the near field, the term "electric field strength" (EFS) or "magnetic field strength" (MFS) shall be used, dependent on whether the resultant electric or magnetic field, respectively, is measured. The EFS shall be expressed as V/m, and MFS as A/m. In this field region, the field measured will be the resultant of the radiation, induction, and quasi-static (1r, $1r^2$, and, if present, the $1r^3$) components, respectively, of the field where r is the distance from the source. Inasmuch as it is not generally feasible to determine the time and space phase relationships of the various components of this field, the energy in the field is similarly indeterminate.

Near Field Region. The region of the field of an antenna between the reactive near-field region and the far-field region wherein radiation fields predominate and wherein the angular field distribution is dependent upon distance from the antenna. Notes: (1) If the antenna has a maximum overall dimension which is not large compared to the wavelength, this field region may not exist. (2) For an antenna focused at infinity, the radiating near-field region is sometimes referred to as the Fresnel region on the basis of analogy to optical terminology.

Normal Distribution. The distribution of random variables found frequently in nature. The principal characteristics of the normal law are: (1) It is symmetrical. Negative and positive deviations of equal magnitude are equally likely to occur. (2) It is a continuous function rather than a discrete function. It assigns a definite probability to every finite deviation. There are no excluded cases. (3) There is just one probable result, and this is identical with the first expectation of the variable.

Susceptibility Threshold. The amount of signal power which will cause minimum perceptible interference or degradation in the performance of the test item.

Test Bed. The test bed is the data base for the EMETF Analytical Facility. It consists of the Deployment File, which includes the frequency assignments, netting, and unit posture as defined by the scenario, and the Frequency Allocation to Equipment File, which includes the technical data on emitters, transmitters, receivers, and antennas.

Test Bed Deployment. The test bed deployment contains the geometric information regarding friendly and/or enemy communications-electronics systems and equipments; the nominal equipment characteristics of all emitters, transmitters, receivers, and antennas; and the frequency assignment, netting, and unit posture as defined by the scenario.

APPENDIX E
ABBREVIATIONS

C-E	communications-electronics
EMI	electromagnetic interference
EMR	electromagnetic radiation
EMRE	electromagnetic radiation effects
MTP	Materiel Test Procedure
RF	radio frequency
TC	Technical Characteristics
TOP	Test Operations Procedure